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शिरो परि पावर लाइनों तथा उच्च वोल्टता के उपस्करों के विद्युत चुम्बकीय व्यक्तिकरण संबंधी गुणधर्म

भाग 2 सीमा ज्ञात करने की कार्यविधि एवं मापन पद्धतियाँ

Indian Standard

ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS OF OVERHEAD POWER LINES AND HIGH VOLTAGE EQUIPMENT

PART 2 METHODS OF MEASUREMENT AND PROCEDURE FOR DETERMINING LIMITS

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CONTENTS

NATIONAL FOREWORD

This Indian Standard (Part 2) which is identical with CISPR Pub 18-2 : (1986) 'Radio interference characteristics of overhead power lines and high-voltage equipment — Part 2 : Methods of measurement and procedure for determining limits' issued by the International Special Committee on Radio Interference (C. I. S. P. R.) of the International Electrotechnical Commission (IEC), was adopted by the Bureau of Indian Standards on the recommendation of the Electromagnetic Compatibility Sectional Committee (LTD 22), and approval of the Electronics and Telecommunication Division Council.

The text of C. I. S. P. R. standard has been approved as suitable for publication as Indian Standard without deviations. Certain terminology and conventions are however not identical with those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear, referring to this standard, they should be read as 'Indian Standard'.

b) For the purpose of this standard, only the metric dimensions given in C. I. S. P. R. Pub shall apply.

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Indian Standard

ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS OF OVERHEAD POWER LINES AND HIGH VOLTAGE EQUIPMENT

PART 2 METHODS OF MEASUREMENT AND PROCEDURE FOR DETERMINING LIMITS

SCOPE AND OBJECT

This publication applies to radio noise from overhead power lines and high-voltage equipment which may cause interference to radio reception, excluding the fields from power line carrier signals.

The frequency range covered is 0.15 MHz to 300 MHz.

The general procedure for establishing the limits of the radio noise field from the power lines and equipment is given, together with typical values as examples, and methods of measurement.

The clause on limits concentrates on the low frequency and medium frequency bands as it is only in these that ample evidence, based on established practice, is available. No examples of limits to protect reception in the frequency band 30 MHz to 300 MHz have been given, as measuring methods and certain other aspects of the problems in this band have not yet been fully resolved. Site measurements and service experience have shown that levels of noise from power lines at frequencies higher than 300 MHz are so low that interference is unlikely to be caused to television reception.

The values of limits given as examples are calculated to provide a reasonable degree of protection to the reception of broadcasting at the edges of the recognized service areas of the appropriate transmitters in the a.m. radio frequency bands, in the least favourable conditions likely to be generally encountered. These limits are intended to provide guidance at the planning stage of the line and standards against which the performance of the line may be checked after construction and during its useful life.

The measuring apparatus and methods used for checking compliance with limits shall conform to C.I.S.P.R. specifications, for example C.I.S.P.R. Publication 16: C.I.S.P.R. Specification for Radio Interference Measuring Apparatus and Measurement Methods. For the frequency range above 30 MHz, the measuring methods are still under consideration by C.I.S.P.R. although some basic aspects are given in C.I.S.P.R. Publication 16.

1. Measurements

1.1 *Measuring instruments*

1.1.1 *Response of a standard C.I.S.P.R. measuring set to a.c. generated corona noise*

C.I.S.P.R. Publication 16 specifies the response characteristic of a measuring set to periodically repeated pulses, according to their repetition frequency, for a number of measuring sets of differing frequency range and bandwidth including the range 0.15 MHz to 30 MHz and a bandwidth of 9 kHz.

Figure 1, page 74, indicates the form these pulses take as they progress through the various stages of the measuring set. However, in the special case of corona pulses generated by high-voltage a.c. power systems, the individual pulses are not equally spaced throughout a cycle but occur in closely packed groups or bursts around the peaks of the voltage waveform. A burst has a duration not exceeding 2 ms to 3 ms and this is followed by a quiescent no-corona period.

Owing to its inherent time constants, a C.I.S.P.R. measuring set is unable to respond to individual pulses within a burst, which is seen as a single pulse whose amplitude is discussed below.

Hence, the pulse repetition frequency, in the meaning of the C.I.S.P.R. definition, is constant at $2f$ (where f is the power system frequency) for single phase and $6f$ for three-phase single or multi-circuit systems, provided that the individual circuits are part of the same system.

Figure 2, page 75, indicates the usual case where individual corona pulses generated around the positive peaks of the voltage waveform are much greater in amplitude than those generated around the negative peaks. Hence in a three-phase power line there are three bursts of higher amplitude and three bursts of lower amplitude noise during each period of $1/f$.

Also, in the measurement of the radio noise field in the close vicinity of an operational line, the measuring set aerial is not located at the same distance from all the phase conductors. Then because a quasi-peak detector responds only to the higher amplitude bursts and disregards the lower ones, rules of summation of the radio noise generated by the individual phases of a line can be formulated which are specific to the C.I.S.P.R. characteristics and are given in Clause 2 of C.I.S.P.R. Publication 18-3: Radio Interference Characteristics of Overhead Power Lines and High-voltage Equipment, Part 3: Code of Practice for Minimizing the Generation of Radio Noise. It should be noted that the loudspeaker of a radio receiver, and consequently the listener, perceives the overall generated noise.

To examine the response of the C.I.S.P.R. measuring set to a given burst of pulses, it should be borne in mind that each individual pulse becomes, at the output of the amplifier of Figure 1 of pass-band Δf, a damped oscillation whose duration can be taken as approximately 2/B, or 0.22 ms for 9 kHz. When there is a large number of pulses distributed at random within a burst, the resulting oscillations will overlap randomly and the overall quasi-peak signal will be approximately equal to the quadratic sum of the individual quasi-peak values. This statement, which is difficult to prove mathematically, has been well proven by experience and justifies the use, in quasi-peak detection, of the quadratic summation law which would moreover be rigorous if the noise levels were expressed in r.m.s. values.

1.1.2 *Other measuring instruments*

Measuring instruments differing from standard C.I.S.P.R. instruments are referred to in Appendix A although measuring apparatus having detectors other than quasi-peak are referred to in C.I.S.P.R. Publication 16.

1.2 *C.I.S.P.R. site measurements – 0.15 MHz to 30 MHz range*

1.2.1 *Measurement frequency*

The reference measurement frequency is 0.5 MHz. It is recommended that measurements are made at a frequency of 0.5 MHz ± 10% but other frequencies, for example 1 MHz, may be used. The frequency of 0.5 MHz (or 1 MHz) is preferred because, usually, the level of radio

noise at this part of the spectrum is representative of the higher levels and also because 0.5 MHz lies between the low and medium frequency broadcast bands.

Because of the possibility of error due to the presence of standing waves, it is inadvisable to rely on the measured value of the radio noise field at a single frequency but to draw a mean curve through the results of a number of readings throughout the noise spectrum. Measurements should be made at, or near, the following frequencies: 0.15, 0.25, 0.5, 1.0, 1.5, 3.0, 6.0, 10, 15 and 30 MHz although, clearly, frequencies at which interference to the wanted noise is received, should be avoided.

1.2.2 *Aerial*

The aerial shall be an electrically-screened vertical loop, whose dimensions are such that the aerial will be completely enclosed by a square having a side of 60 cm in length. The balance shall be such that in a uniform field the ratio between the maximum and minimum indications on the measuring equipment when the aerial is rotated shall not be less than 20 dB. The base of the loop should be about 2 m above ground. The aerial shall be rotated around a vertical axis and the maximum indication noted. If the plane of the loop is not effectively parallel to the direction of the power line, the orientation should be stated.

The measurements may be carried out using a vertical rod aerial although this method is not preferred because of the higher instability of the electric component of the radio noise field and because of possible electric induction effects from the power-frequency voltage.

A check shall be made to ensure that the supply mains, if used, or other conductors connected to the measuring apparatus do not affect the measurements.

1.2.3 *Distance of measurement*

It is necessary to determine the lateral profile of the radio noise field. For purposes of comparison, the reference distance defining the noise level of the line shall be 20 m. The distance shall be measured from the centre of the loop to the nearest conductor. The height of the conductor above ground should be noted. If the field is plotted as a function of the distance using a logarithmic scale, a substantially straight line is obtained. Under these conditions, the field at 20 m is readily obtained by interpolation or extrapolation (see Figure 3, page 75).

1.2.4 *Position of measurement*

To determine the radio noise performance of a line certain positions of measurement should be avoided; but these restrictions would not apply when an investigation into a case of interference is being carried out.

Measurements should be made at mid-span and preferably at several such positions. Measurements should not be made near points where lines change direction or intersect.

Sites at an abnormal height of span should be avoided. The measuring site should be flat, free from trees and bushes and be some distance from large metal structures and from other overhead power and telephone lines.

Ideally the measuring site should be at a distance greater than 10 km from a line termination, in order to avoid reflection effects and consequently inaccurate results, but lower voltage distribution lines are sometimes too short to enable this condition to be met. However, the

results of measurements (Reference [33]* of C.I.S.P.R. Publication 18-1: Radio Interference Characteristics of Overhead Power Lines and High-voltage Equipment, Part 1: Description of Phenomena) indicate that the level of the radio noise field in the absence of reflections corresponds to the geometric mean of the maximum and minimum values, in microvolts per metre (μV/m), of the frequency spectrum from a line subjected to reflections.

If the line is transposed, the measuring site should be located as far as possible from the transposition towers.

The atmospheric conditions should be approximately uniform along the line. Measurements under rain conditions will be valid only if the rain extends over at least 10 km of the line on either side of the measuring site.

1.2.5 *Additional information to be given in the report*

To ensure that extraneous interference is not influencing the measurement of the levels of the line radio noise field it may be necessary to measure the noise levels with the line de-energized.

When the results of the measurements are reported, as much relevant information as possible should be given on the line and on the conditions under which the measurements were carried out.

Appendix B gives a list of such information.

1.3 *C.I.S.P.R. laboratory measurements*

1.3.1 *Introduction*

This clause gives the method to be used for the measurement, in a laboratory or test area, of radio noise generated by items of plant and components used on high-voltage lines and in substations, such as circuit-breakers, bushings, insulators and fittings. This method is valid for type tests and for routine or sample tests and also for investigational tests.

It is usual practice to carry out laboratory measurements of radio noise in a prescribed test circuit by measuring conducted quantities (current or voltage) and not the emitted field.

Furthermore, the selection of test conditions should be based on the following principle: ideally, the measurements should be made with the conditions and circuit simulating, as far as possible, actual service conditions and, if necessary, the most severe conditions likely to occur for the type of apparatus tested. Before the establishment of a reliable method of radio noise testing in a laboratory, reliance was placed on the voltage at which inception or extinction of visual corona occurred on the test object. The voltages so determined were very dependent on the observer and this method is now being replaced by the laboratory measurements described below.

1.3.2 *State of the test object*

It is well known that radio noise levels produced by high-voltage equipment are very dependent on the state of the surface of the item of equipment. In laboratory tests, the state of a particular test object should consequently be clearly defined with regard to the following aspects:

a) new or already used;

b) clean or slightly polluted; the nature of the pollution should be specified;

c) dry, slightly damp, or wet (for example artificial rain conditions);

d) combination of these states, for example polluted and damp.

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* The figures in square brackets refer to "Bibliography and references" of C.I.S.P.R. Publication 18-1 (pages 69 to 71) and of this part (page 57).

Generally, standards and normal practice are restricted to laboratory tests on clean and dry objects, reproducibility of the other test conditions (dampness, pollution) being often difficult to achieve. However, tests on objects submitted to (standardized) rain conditions may be very useful, since these conditions occur frequently in practice and may lead to significantly higher radio noise levels than dry conditions.

When only one surface condition is taken into consideration, it is desirable, in order to be as close as possible to the practical conditions, that the tests be performed on adequately polluted and wet samples, at the normal operating voltage.

When the object is to be tested in a clean and dry state, it may be wiped with a dry cloth to remove dust and fibres that might affect the surface.

Unless otherwise stated, test conditions described in this clause are valid for used, wet and/or polluted objects as well as for new, clean and dry objects.

1.3.3 *Test area*

The tests should preferably be performed inside a screened room which is large enough to prevent the walls and the floor from having any significant effect on the distribution of the electric field at the surface of the test object. Circuits, for example power and lighting, entering the screened test area should, ideally, be filtered so as to avoid the introduction of radio noise present in the environment (see Sub-clause 1.3.11).

If a screened room is not available, the tests may be carried out at any place where the background noise level is sufficiently low compared with the levels to be measured (see Sub-clause 1.3.11).

1.3.4 *Atmospheric conditions*

The normal reference atmosphere for tests described herein is:

- temperature: 20 °C;
- pressure: 1.013×10^5 N/m^2 (1013 mbar);
- relative humidity: 65%.

However these tests may be performed under the following atmospheric conditions:

- temperature: between 15 °C and 35 °C;
- pressure: between 0.870×10^5 N/m^2 and 1.070×10^5 N/m^2 (870 mbar and 1070 mbar);
- relative humidity (for tests on objects in the dry state): 45% to 75%.

In the case of investigational tests, other conditions may be selected according to the test objective.

When tests are made on a dry object, it shall be in thermal equilibrium with the test area atmosphere to avoid any condensation on the surface of the object.

As far as the radio noise levels generated by a test object are concerned, the effects of changes in atmospheric conditions, within the above limits, from the normal reference conditions are little known. Thus no correction shall be applied to the measured results but the air temperature, air pressure and relative humidity obtaining during the tests shall be recorded.

1.3.5 *Test circuit – Basic diagram*

Figure 4, page 76, shows the principle of the test circuit. The radio-frequency currents generated by the test object flow through that part of the circuit shown by heavy lines which include impedance Z_s and resistance R_1. The radio-frequency rejection filter F virtually

prevents these currents from flowing in the high-voltage connections to the transformer and, conversely, any interference currents from other sources present in this high-voltage connection are attenuated by the filter before entering the high frequency part of the circuit. Ideally the impedance of Z_s should be zero at the measurement frequency and infinite at the power supply frequency. Also if R_L represents the resistive load of the test object in service, for example the characteristic impedance of a high voltage line, the radio noise voltage which the test object would inject onto a line conductor or substation connection may be measured across R_L.

C.I.S.P.R. Publication 16 specifies a value of 300 Ω for R_L and in a practical test circuit (see Figure 5, page 76), R_L is the equivalent resistance of R_2 in series with the parallel combination of R_1 and the input resistance of the measuring set, R_m.

The test consists of taking measurements, expressed in microvolts (or in decibels relative to 1 μV) of the pulse-type voltages appearing across a fraction of R_L when a given power-frequency voltage is applied to the object under test.

1.3.6 *Practical arrangement of the test circuit*

Figure 5 shows the standard test circuit which should be used for the laboratory measurement of the radio noise voltages generated by medium and/or high voltage equipment. The connections to the measuring set are shown in a simplified form in Figure 5 and, depending on the distance between the measuring set and the test circuit, the arrangement shown in either Figure 6, page 77 or Figure 7, page 77, is incorporated into the circuit of Figure 5.

Note. – In the special, limited, case of the need for rapid comparative measurements to be made on a number of identical small objects, such as cap and pin insulator units for overhead lines, the special test circuit of Figure 8, page 77, may be used. The decoupling capacitor C_m may be omitted when the number of test objects exceeds five.

The impedance Z_s in the basic circuit of Figure 4, page 76, can consist of *i)* a series circuit L_2C_2 or *ii)* simply a capacitor C_3, as shown in Figure 5.

i) L_2C_2 is tuned to the measurement frequency along with L_1 in parallel with C_1, forming the rejection filter F. The advantage of this arrangement is that C_2 may have a relatively low value of capacitance, say 50 pF to 100 pF and therefore be cheaper, but the disadvantage is that measurements at frequencies other than the reference frequency involve the retuning of L_2C_2 and L_1C_1.

ii) As stated in Item *d)* of Sub-clause 1.3.7, a value of 1 000 pF for C_3 should be satisfactory, which makes an inductor in series with C_3 unnecessary and this part of the test circuit aperiodic. By making the rejection filter F also aperiodic by using, for example, an inductor damped by parallel resistors, measurements at frequencies other than the reference frequency can be carried out relatively simply. If, however, the laboratory or test area is near to industrial premises where high levels of radio noise can be produced, a very high filter impedance is usually required (see Item *c)* of Sub-clause 1.3.7).

1.3.7 *Test circuit components*

The components that are used in the test circuit shall meet the following requirements.

a) High-voltage connections

The radio noise level produced by the high-voltage connections and terminations of the test circuit shall be insignificant compared with the values to be measured from the test object at the test voltage.

b) High-voltage transformer T_1

This transformer shall provide a voltage waveform consistent with the specifications of IEC Publication 60–2: High-voltage Test Techniques, Part 2: Test Procedures.

c) Rejection filter F

Filter F shall have an impedance of not less than 20000 Ω, corresponding to an attenuation of at least 35 dB, in either direction at the measurement frequency.

To be fully effective, the filter should be located as near as possible to the high frequency part of the test circuit. When the filter consists of a tuned circuit (L_1C_1), it should be tuned to the measurement frequency by using, for example, a signal generator connected across the secondary terminals of transformer T_1. Tuning is achieved by varying C_1 to give a minimum reading on the measuring set. The filter impedance may be assessed by measuring its insertion loss by taking the difference in the measuring set readings with the filter short-circuited and then with the short-circuit removed.

At the reference measurement frequency of 0.5 MHz ± 10%, the value of L_1 should be about 200 μH whereas C_1 should be variable up to a maximum of 600 pF.

d) Measuring impedance

The impedance between the live conductor and earth ($Z_s + R_L$ in Figure 4, page 76) shall be 300 ± 40 Ω with a phase angle not exceeding 20°, at the measurement frequency.

A coupling capacitor C_3 (Figure 5, page 76) may be used in place of Z_s provided that the capacitance of C_3 is at least five times greater than the capacitance to earth of the test object and its high voltage connection. In practice, a value of 1000 pF should be satisfactory for C_3.

Capacitor C_3 shall be capable of withstanding the maximum test voltage and have a low partial discharge level at that voltage.

1.3.8 *Measuring set connections*

The more usual method of connecting the measuring set to the test circuit, that is, where the length of cable is less than about 20 m and co-axial cable is used, is shown in Figure 6, page 77. Where the length of cable is greater than 20 m, balanced screened cable is used, and this arrangement is shown in Figure 7, page 77.

a) Matching resistor R_1

To reduce the possibility of errors, due to reflections within the measuring set connections, the co-axial cable, in the case of Figure 6, shall be terminated in its characteristic impedance at each end. Also, in the circuit of Figure 7, the cable/transformer assembly shall be similarly terminated.

The effective input resistance R_m of the measuring set usually provides one matching termination and the other termination is provided by R_1 which shall be of the high stability, non-inductive type.

b) Series resistor R_2

To meet the requirement of 300 Ω resistance across the test object, the input resistance R_m of the measuring set in parallel with R_1 has to be increased using a series resistor R_2 which shall be of the high stability, non-inductive type. In the case of a measuring set where R_m is 50 Ω, the value of R_2 should be 275 Ω.

Note. – In some countries other resistance values are assigned to R_L: for example, the National Electrical Manufacturers' Association (NEMA), of the USA, in its Publication 107 (1964), specifies the value of 150 Ω for R_L. Usually a simple conversion can be applied to the results obtained from tests to other specifications. This is because a radio noise source in a test object almost invariably produces a constant current, provided R_L is within the range 100 Ω to 600 Ω and the voltage measured across R_L is simply proportional to its value.

c) Inductor L_3

This inductor provides a low-impedance path at power frequency to divert, from the measuring set and its associated components, power frequency currents which flow in C_2 or C_3. At the reference measurement frequency of 0.5 MHz, L_3 shall have a value of at least 1 mH, with a low self-capacitance, to avoid errors exceeding 1% or 0.1 dB. For safety reasons, L_3 should be robust and have sturdy and secure electrical connections.

d) Spark gap

To reduce the possibility of high voltages appearing on the measuring set connections, the provision of a protective spark gap across L_3 is recommended. This spark gap should preferably be of the gas-filled type with a maximum breakdown voltage of 500 V on a power frequency sine wave (see note below).

Note. – In the event of a relatively high power frequency voltage appearing across the spark gap, due for example to a failure of the inductor L_3 or its connections, there could be an increase in the test circuit background noise level, because of corona discharges at the electrodes of the spark gap.

e) Balanced cable and balun transformers (T_2 and T_3)

Where the test object is large and/or where very high voltages are involved, the measuring set may have to be located at some distance from the base of (C_2, L_2) or C_3, where R_1 and R_2 are located. Under such conditions the length of co-axial cable shown in Figure 6, page 77, may exceed 20 m and, to reduce the possibility of the measurements being affected by interference picked up on this cable, it is recommended that the arrangement shown in Figure 7, page 77, should be used.

The balun or coupling transformers T_2 and T_3 should be located close to R_1/R_2 and to the measuring set, respectively, and the connection between the transformers should be made by means of a balanced screened cable. Short lengths of co-axial cable should be used to connect T_2 to R_1/R_2 and T_3 to the measuring set and all these cables should have suitable characteristic impedances to ensure correct matching.

f) Measuring set

To comply with C.I.S.P.R. recommendations, the measuring set shall be consistent with the specifications of C.I.S.P.R. Publication 16. If a measuring set with different characteristics is used, a conversion of the results into values which would have been obtained with a C.I.S.P.R. instrument is usually possible, but this can lead to some inaccuracy. This conversion should be carried out as detailed in Sub-clause 1.1.

1.3.9 *Mounting and arrangement of test object*

The object under test shall be mounted and arranged in accordance with the requirements of the standard applicable to the particular apparatus concerned (for example, IEC Publication 437: Radio Interference Tests on High-voltage Insulators). When no such standard is available, the test object shall be arranged, as far as possible, in the same manner and with the same circuit configuration as exist in service.

The object under test shall be provided with all its normal fittings, such as arcing horns and stress-control fittings, that may affect the distribution of the electric field at the surface of the

test object. Where the test object can be in more than one condition, for example a circuit-breaker which can be open or closed, it shall be tested in each of these conditions.

The high-voltage connections to the object under test shall be short and shall not contribute to the measured values of radio noise from the test object nor influence the distribution of the electric field at its surface.

The coupling impedance, L_2 C_2 (or C_3) shall be located near to the test object without significantly disturbing the distribution of the electric field at the surface of the test object.

1.3.10 *Measurement frequency*

The reference measurement frequency is 0.5 MHz. It is recommended that measurements are made at a frequency of 0.5 MHz ± 10% but other frequencies, for example 1 MHz, may be used.

1.3.11 *Checking of the test circuit*

The test circuit shall be arranged so as to permit an accurate measurement of the radio noise level generated by the object under test. Any interference from outside the test circuit, including the supply, or from other parts of the circuit, shall be at a low level and, preferably, at least 10 dB below the level specified for the test object.

With the specified test voltage applied to the circuit, the level of background noise shall be at least 6 dB below the lowest level to be measured. These conditions may be checked by substituting a similar, but noise-free, test object for the object under test.

Background noise levels may be relatively high when the tests are made in an unscreened area, especially when there are industrial premises nearby. When these high levels are of short duration, this condition may be acceptable provided that the quiet periods are of sufficient duration for a reliable measurement to be made and that, during the measurements, the character of the interfering peaks can be clearly distinguished from that of the noise being generated by the test object, possibly by means of an oscilloscope or a loudspeaker.

Interference may also result from broadcast stations which may be overcome by selecting a measurement frequency, within the specific tolerance, which is clear of interference. The use of a resonant circuit L_1C_1, which is correctly tuned, as the rejection filter F, can often be most effective in reducing background noise.

1.3.12 *Calibration of the test circuit*

The test circuit shown in Figure 5, page 76, together with the circuit shown in either Figure 6 or Figure 7, page 77, shall be calibrated to obtain the value of the correction factor that shall be applied to the measuring set readings. This factor is the sum of the circuit attenuation and the resistance network factor, both expressed in decibels (dB). Such calibration is required where the test assembly is being used for the first time, or has been re-arranged, or where the test object has been changed to one of a significantly different capacitance. The power supply to the high-voltage transformer should be disconnected during calibration.

a) Circuit attenuation A

Before starting the calibration, the rejection filter F shall be tuned, if applicable, as described in Item *c)* of Sub-clause 1.3.7, to the particular measurement frequency. A signal generator with an output impedance of at least 20000 Ω shall then be connected in parallel with the test object, the test circuit being complete, as shown in Figure 5 together with the circuit shown in either Figure 6 or Figure 7. (Such a generator is easily arranged by connecting a 20000 Ω resistor in series with the output of a standard signal generator.) The generator shall be set to

deliver a sine wave output of 1 V, at the measurement frequency, which will inject a current of about 50 μA into the test circuit. This current will ensure that, with a C.I.S.P.R. measuring set, its reading will be well in excess of the usual background noise level. This reading, in decibels, of the measuring set shall be noted.

With the settings of the generator unchanged, the test object shall be disconnected from the high-voltage part of the test circuit and connected as shown in Figure 9, page 78. The new reading, in decibels, of the measuring set shall also be noted and the difference between the two readings is the circuit attenuation A.

Notes 1. – To avoid removing R_1 and R_2 from the test circuit during the calibration procedure, other high-stability, non-inductive resistors of the same value may be used.

2. – In Figure 9 the test object may be replaced by an equivalent capacitance, if this is known.

b) Resistance network factor R

Levels of radio noise voltage generated by the types of apparatus being considered in this clause are usually expressed in decibels relative to 1 μV across 300 Ω.

Then, if $R_1 = R_m$, the network factor will be as follows:

$$R = 20\lg \frac{600}{R_1} \text{ , expressed in decibels.}$$

The radio noise level of the object being tested is then given by

$$V\,(\text{dB}/1\,\mu\text{V}/300\,\Omega) = V_m + A + R$$

V_m being the voltage, in decibels relative to 1 μV, indicated by the measuring set and corresponding to its input voltage.

Notes 1. – A less complicated alternative method of overall calibration of the test circuit can be carried out in a single operation if a *calibrated* sine-wave current generator is used. This method involves an accurate measurement of both the output voltage V_0 of the signal generator and the value of a 20000 Ω resistor R_r in series with the generator output. Then when the signal generator, with the 20000 Ω series resistor, is connected in parallel with the test object a reading V_1 (μV) appears on the measuring set which corresponds to the current i_1 injected into the circuit:

$$i_1 = \frac{V_0}{R_r} \text{ in microamperes}$$

Under these circumstances, the radio noise level of the apparatus being tested is directly given by:

$$V\,(\text{dB}/1\,\mu\text{V}/300\,\Omega) = V_m + 20\lg 300\,\frac{i_1}{V_1}$$

where V_m is the voltage, in decibels relative to 1 μV, indicated by the measuring set at the time of the test.

2. – The sine-wave signal generator may be replaced by a pulse generator with a constant frequency spectrum, at least up to the measurement frequency. Correspondence of amplitudes between pulse and sinusoidal signals should meet the data included in Sub-clause 2.1 of C.I.S.P.R. Publication 16.

1.3.13 *Test procedure*

Radio noise generated by high-voltage equipment depends mainly on the distribution of the electric fields at the surface of the equipment. Ideally, the distribution in service should be reproduced during tests in the laboratory.

The radio noise level generated by a test object is not entirely determined by a particular value of the test voltage. An hysteresis effect often occurs, with the result that noise may or may

not be present at a given test voltage, as it depends on whether this voltage was reached by decreasing or increasing values. Pre-conditioning of the test object, by subjecting it to a voltage which is equal to or greater than the specified test voltage for a specific period of time, can also have an effect on the measured level of radio noise.

The procedure for applying the test voltage should therefore be accurately specified.

The test voltage shall be a sine wave at power-supply frequency and be consistent with IEC Publication 60-2. It shall be applied either:

a) between phases of the object under test (for example a three-phase circuit-breaker), in which case the test voltage is related to the system's line voltage, or

b) between phase and earth (for example a complete insulator string), in which case the test voltage is related to the system's phase voltage.

The test voltage of the object to be tested is usually specified in the standard applicable to the type of object. In the absence of such a specification, the test voltage shall be 1.1 times the nominal voltage of the system or the rated voltage of the equipment ($U/\sqrt{3}$ for apparatus tested with respect to earth). In some cases, the test voltage is agreed between manufacturer and purchaser at a value between 1.1 and 1.4 times the nominal voltage of the system or the rated voltage of the equipment.

A voltage 10% higher than the specified test voltage should be applied to the object under test and maintained for at least 5 min. The voltage should then be decreased in steps to 30% of the specified test voltage, raised in steps to the initial value, maintained there for 1 min and, finally, decreased in steps to the 30% value. Each voltage step should be approximately 10% of the specified test voltage. At each step a radio noise measurement should be made and the results obtained during the last decreasing run should be plotted against the applied voltage, the curve so obtained being the radio noise characteristic of the test object.

When significant variations are likely to occur in the radio noise level from a number of items of equipment of the same type, the measurements should be done on several samples. Then the typical radio noise characteristic will be the average curve obtained when all the results are taken into account. When the number of samples is sufficient, a level dispersion may also be evaluated. When compliance with limits is required, it may be appropriate to use the statistical method given in Section Nine of C.I.S.P.R. Publication 16.

1.3.14 *Related observations during the test*

Additional observations may profitably be carried out at the same time as the radio noise measurements, in order to locate any noise sources on the test object and assist in establishing the cause of possible defects. A visual observation, if necessary by means of binoculars in a darkened laboratory, will enable even extremely small points of corona discharge to be located. Such observations may be confirmed by means of photographs with long exposure times, or by means of an image amplifier. If it is impossible to darken the laboratory sufficiently, the points of discharge may be located to some extent by ear or, preferably, by an ultrasonic detector which is much more directional.

1.3.15 *Data to be given in test report*

In addition to the specification of the apparatus under test, the test report should also give the following data:

- state of the test object:
  - new or already used,
  - clean or polluted (nature and degree of pollution),
  - dry, damp or wet;
- atmospheric conditions:
  - temperature,
  - barometric pressure,
  - relative humidity,
  - presence or absence of rain (standardized artificial rain);
- test circuit, including any difference from the standard C.I.S.P.R. circuit;
- arrangement of the object under test;
- background noise level;
- test voltage with detailed procedure of its application;
- measured radio noise levels, expressed in decibels relative to 1 μV across 300 Ω (these can be given in the radio noise characteristic);
- results of any observations regarding the location of noise sources;
- comparison between the measured levels and any specified limits.

1.4 *Statistical evaluation of the radio noise level of a line*

C.I.S.P.R. Publication 16 describes statistical sampling methods for establishing the compliance of mass-produced appliances with C.I.S.P.R. limits. The so-called 80%/80% rule is based on the application of statistical techniques that have to give the consumer an 80% degree of confidence that 80% of the appliances of a type being investigated are below the specified radio noise limit. The method is based on the non-central *t*-distribution (sampling by variables) and the spirit of the 80%/80% C.I.S.P.R. rule is interpreted for overhead lines in that the radio noise level should not exceed the limit for more than 80% of the time with at least 80% confidence.

Definitions of readings and sets of measurements:

1) A reading is a single measurement (in decibels), at a given location, under given meteorological conditions. If the meter readings fluctuate, then an average value taken over a period of at least 10 min should be used.
2) Each set of measurements consists of averaging the readings taken, for a given meteorological condition, at three different locations approximately evenly distributed along the line. Not more than one set of measurements should be taken on any particular day for the given meteorological conditions. The three different locations will help to eliminate the effects of local irregularities (for example standing waves), although, as stated in Sub-clause 1.2, positions of measurement where unrepresentative readings are likely to be obtained should be avoided.

Number of measurements:

1) using the measurement techniques described in Sub-clause 1.2, at least 15 but preferably 20 or more sets of measurements should be taken.
2) The number of sets of measurements for each weather condition (dry, rain, snow, etc.) must be proportional to the frequency of occurrence of each weather condition for the area.

Compliance with a given limit of noise is judged from the following relationship taken from Section Nine of C.I.S.P.R. Publication 16:

$$\bar{X} + kS_n \leq L$$

where:
L is the permissible upper limit of radio noise
$\bar{X}$ is the mean value of the (n) number of sets of measurements of the radio noise level of the line, namely:

$$\bar{X} = \frac{X_1 + X_2 \ldots + X_i + \ldots X_n}{n}$$

S_n is the standard deviation of the (n) sets of measurements, namely:

$$S_n = \sqrt{\frac{\Sigma_1^n (X_i - \bar{X})^2}{n - 1}}$$

k is the constant depending on (n) and is determined in such a way that the above stated 80%/80% rule is satisfied.

The k value to be used for (n) number of sets of measurements is shown in the table below.

n	15	20	25	30	35
k	1.17	1.12	1.09	1.07	1.06

This formula, based on a limited number of samples, is similar to that relating to a Gaussian distribution valid for an infinite number of samples, the samples being represented by sets of measurements.

In the formula, S_n can be compared with the standard deviation relating to an infinite number of samples and k depends on both the required confidence (80%/80%) and on the number of samples. The lower the number of samples the higher the value of k becomes for any percentage specified to meet the limit, with a given confidence.

Studies indicate that even for a non-Gaussian distribution, the use of the above statistical method does not introduce a significant error provided that at least 15 but preferably 20 or more sets of measurements are used in the evaluation.

2. Methods for derivation of limits

2.1 *Introduction*

The C.I.S.P.R. has for many years considered the question of limits of radio noise from overhead power lines and high-voltage equipment in order to safeguard radio and television broadcast reception. The degree of annoyance caused by radio noise is determined by the signal-to-noise ratio at the receiving installation. For similar subjective annoyance, the signal-to-noise ratio depends on the nature of the noise source. Based on a required signal-to-noise ratio, many factors affect the acceptable level of noise, such as minimum signal level to be protected, minimum distance between power line and receiving location, effects of weather, etc. Further difficulties exist in specifying the conditions for verifying compliance with limits. For example, views are divided on whether measurements should be carried out in fair weather, foul weather, or both. Practically every major factor is subject to statistical variation. It is recognized that international discussions cannot fully resolve these problems. Some countries have, however, laid down mandatory standards on limits of interference from power lines.

There is general agreement by countries participating in C.I.S.P.R. that guidance should be given by it on a simple and effective method for deriving limits on a national basis, taking into account particular conditions the regulatory authority may wish to adopt. Furthermore, it is agreed that the method of deriving limits should be illustrated by examples based on reasonable signal levels, adequate receiver installations and on practical and economical power line designs. The method should enable assessment of the effects of power lines on reception under any particular conditions.

Since a number of arbitrary assumptions about random parameters must be made, which may differ from actual conditions, and since economic factors must also be considered, recommended limits cannot assure 100% protection to 100% of the listeners or viewers. This fact is generally accepted in standardization.

2.2 *Significance of C.I.S.P.R. limits for power lines and high-voltage equipment*

C.I.S.P.R. Recommendation 46/1 "Significance of C.I.S.P.R. Limits" [67]* and Section Nine of C.I.S.P.R. Publication 16, specify a statistical basis for analysing test data to determine compliance with a C.I.S.P.R. limit for mass-produced appliances.

In the case of noise from power lines and high-voltage equipment, this criterion is not directly applicable. It is, however, possible to relate it to the statistical distribution of noise due to the variation of atmospheric conditions. For power lines and equipment, the C.I.S.P.R. limit may be interpreted as the noise level not exceeded for 80% of the time. However, as is discussed in Sub-clause 1.4, this application of the C.I.S.P.R. 80%/80% rule involves a larger number of measurements than is specified in Recommendation 46/1. It must also be realized that an 80% level for conductor corona noise for power lines in moderate climates will usually be a foul-weather level, whereas for dry climates it will usually be a fair-weather level. Regulatory authorities should keep this fact in mind when deciding on adoption of the 80% level.

A different criterion such as average, fair-weather, noise level; maximum, fair-weather, noise level; or even the heavy rain noise level could also be the basis for establishing limits.

2.3 *Technical considerations for derivation of limits for lines*

2.3.1 *Basic approach*

The basic requirement is to obtain an adequate signal-to-noise ratio at the receiving installation for satisfactory reception of broadcast signals. When establishing regulations, it will be the responsibility of the regulatory authority to determine the minimum signal strengths to be protected and the signal-to-noise ratio that will give satisfactory reception. This publication presents the latest information on acceptable signal-to-noise ratios and gives some information on minimum signal levels to be protected. It also shows how the protected signal level and the required signal-to-noise ratio can be combined with the noise level at a reference distance of 20 m from the nearest conductor of the power line to develop a "protected distance". This protected distance represents the minimum distance from the line required to protect the minimum broadcast signal for a certain percentage of the time. For example, if the 80% level is chosen as the basis for the radio noise, then this protected distance will be the minimum distance from the line at which the minimum protected signal can be received 80% of the time with an acceptable signal-to-noise ratio. If the average fair weather noise level is the

* The figures in square brackets refer to "Bibliography and references", page 57.

basis for establishing limits, then this protected distance will be the minimum distance from the line at which the minimum protected signal level can be received for 50% of the time during fair weather with an acceptable signal-to-noise ratio. Similar logic would apply for any other percentage, taken on an all-weather noise distribution curve, or for any other weather condition, for example, steady rain (in this case, reception would be satisfactory 95% of the time, at least in moderate climates).

It should be appreciated that at most locations the signal level will be higher than the minimum and that advantage can sometimes be taken of the directional properties of certain types of receiving aerial to improve the signal-to-noise ratio. On the other hand, there will be cases where the distance between the power line, or high-voltage equipment, and the receiving location will be less than the protected distance. On a statistical basis these factors will often tend to balance each other in such a way as to provide adequate reception even in cases falling within the protected distance. For those so placed who suffer interference, correction techniques may be employed such as remote aerials or connection to cable systems.

2.3.2 *Scope*

2.3.2.1 *Power systems considered*

The radio noise limits discussed in this clause apply to the power system as a whole and not to its individual components such as transformers, insulators, etc. The method of measurement of the noise level of a component is discussed in Sub-clause 1.3 and the relation of this level to that which it would produce 20 m from the nearest conductor of a power line is discussed in Sub-clause 6.2 of C.I.S.P.R. Publication 18-1. All a.c. lines and substations operating at voltages within the range 1 kV to 800 kV are included. At the present time there is insufficient information to allow examples to be provided of the derivation of limits for d.c. lines, although the main principles could be the same. This matter is still under consideration.

The noise limits are based on lateral attenuation laws applicable to typical power lines and on the appropriate C.I.S.P.R. measuring methods and instruments referred to in Clause 1. No well-established data are presently available for substations. For simplicity, however, the same laws may be used as for lines, the reference distance being taken as 20 m from the perimeter fence of the substation. It should be noted that only persistent noise from substations is considered. Transient noise, such as that due to interruption of a power circuit, is not included.

2.3.2.2 *Frequency range*

The frequency range is from 0.15 MHz to 300 MHz, covering specifically the a.m. broadcast bands between 0.15 MHz and 1.7 MHz and the v.h.f. television and f.m. radio bands between 47 MHz and 230 MHz. The intent is to provide protection to "reasonable" signal levels of these services. Since power lines normally produce negligible interference to broadcast reception above 300 MHz and since there is only limited information on noise levels at these frequencies, the bands above 300 MHz are not included at this time.

The definition of "reasonable" will vary with the type of service and part of the world. The International Telecommunications Union (ITU) considers three regions (1, 2 and 3). Regions 1 and 3 are further divided into three zones (A, B and C) based on climatic conditions. Figure 10,

page 79, shows these regions and zones. Within each region and zone, there are specific transmitter power levels, minimum protected signal levels, required co-channel and adjacent channel protection ratios, etc.

In particular the low and medium frequency broadcast bands 0.15 MHz to 0.28 MHz and 0.5 MHz to 1.7 MHz are regulated by the ITU. However, existing practices regarding minimum signal levels to be protected and also regarding protection ratios often differ from the latest recommendations of the ITU. In North America the 0.5 MHz to 1.7 MHz band is regulated by the North American Regional Broadcasting Agreement (NARBA). It should be noted here that some of the differences result from differences in broadcasting philosophies. In Europe, for example, it is usual to have a few omnidirectional transmitters of high power to cover an entire country. In North America, on the other hand, there is a multitude of individual stations, often with highly-directional aerial arrays aiming a signal at a particular city or region of the country. Transmitter power is usually limited to 50 kW and protected received signal levels are generally lower than those specified in Europe.

Note. – The upper and lower limits of the various frequency bands, used for broadcasting and given here, are approximate values. Exact values vary from one region to another and are subject to periodic revisions. (See reference [62] for more details.)

2.3.3 *Minimum broadcast signal levels to be protected*

Individual national authorities should determine the minimum signal levels to be protected from power line noise related to appropriate weather conditions. For the low frequency and medium frequency bands, the ITU [63] has recommended minimum field strengths necessary to overcome natural noise (atmospheric noise, cosmic noise, etc.). For broadcast planning purposes, the ITU has also recommended for information only, nominal usable field strengths. Appendix C gives recommended values for both the minimum and the nominal usable field strengths.

Since natural noise levels vary with time and geographical location, signal levels below these values can sometimes be received satisfactorily and at other times unsatisfactorily, irrespective of power line or other man-made noise.

For the v.h.f. bands, the International Radio Consultative Committee (CCIR) recommended minimum signal levels for Region I are as follows:

Frequency band	Minimum signal strength
Television band I, 47 MHz to 68 MHz	48 dB (1 μV/m)
F.M. radio band II, 87 MHz to 108 MHz	48 dB (1 μV/m) (for mono)
	54 dB (1 μV/m) (for stereo)
Television band III, 174 MHz to 230 MHz	55 dB (1 μV/m)

In North America, signal levels at the edge of the service area of a broadcasting station are specified by NARBA and other standards [64 to 66]. These levels are given in Appendix D.

It is generally accepted that when criteria for the protection of TV in bands I and III have been fixed, f.m. monoaural radio is automatically protected. The protection requirements for f.m. stereo radio are under consideration. Similarly, the intermediate bands, such as short wave, will automatically be protected by the medium wave broadcast band protection. However, in certain cases, there may be telecommunication services requiring different

protections. These should be taken into account by national authorities when limits are being considered.

It should be borne in mind that all of these minimum signal levels are related to protection against interference from other radio signals or from natural noise. Interference from power line noise has not been considered.

With the widely differing values adopted for usable signal levels for different zones of the world, daytime and night time, the term "reasonable signal level" has to be established with regard to the factors relevant to the different levels. It is inevitable that if low levels are adopted, radio noise from power lines should be viewed in comparison with other sources of interference and the protected distance between the power line and receiver should be increased and/or the acceptable signal-to-noise ratio reduced.

2.3.4 *Required signal-to-noise ratio*

2.3.4.1 *Radio broadcasting*

No exact recommendations as to acceptable signal-to-noise ratios have yet been devised for noise from power lines. For planning purposes, the ITU recommend a wanted-to-interfering signal ratio of 30 dB. NARBA levels are based on a ratio of 26 dB.

For similar ratios, power line noise may represent somewhat less objectionable interference than does co-channel interference.

The technical literature contains results of a number of investigations of the required signal-to-noise ratio for satisfactory reception in the presence of power line noise. These are summarized in Appendix E. The required ratios for various qualities of reception from "entirely satisfactory" to "speech unintelligible" are provided. National regulatory authorities may specify the quality of reception they wish to protect. It should be borne in mind that the signal-to-noise ratio depends largely on the receiver bandwidth. The ratios given in Appendix E are based on the signal being measured on an average or r.m.s. reading meter and the noise being measured on a C.I.S.P.R. meter with a quasi-peak detector. For a.m. reception, the C.I.S.P.R. meter has a 9 kHz bandwidth. The level of an a.m. broadcast signal measured on the C.I.S.P.R. meter will be about 3 dB higher, depending on the modulation amplitude, since the quasi-peak detector produces an output which approaches the peak of the modulation envelope. This effect will, of course, not apply if the measurements are made on an unmodulated signal.

2.3.4.2 *Television broadcasting*

The required signal-to-noise ratios for television reception are less definite than those for radio. For the European television standards, 40 dB appears to be generally acceptable (the bandwidth of the C.I.S.P.R. meter being 120 kHz). However, tests carried out in the United Kingdom with a positive modulated black and white picture showed that this value could be reduced by up to about 5 dB. For the North American television standards, several limited tests have suggested 40 dB for black and white television [58]. Tests on colour television are currently being carried out. Further consideration of all these issues is required.

The repetition rates of noise pulses due to corona and to gap-type discharges may differ considerably. This may have a large influence on the degree of interference produced on a television picture. Although there is not much data available, this should be considered when establishing acceptable signal-to-noise ratios for television reception.

2.3.5 *Conversion of measured values*

2.3.5.1 *Attenuation laws*

The rate of lateral attenuation of radio noise, for distances between about 20 m and 100 m from the nearest conductor of a line, varies in different frequency ranges and also depends on the configuration of the line. The following approximate values should provide satisfactory results:

- 0.15 MHz to 0.4 MHz, noise level decreases as $D^{-1.8}$
- 0.4 MHz to 1.7 MHz, noise level decreases as $D^{-1.65}$
- 30 MHz to 100 MHz, noise level decreases as $D^{-1.2}$
- 100 MHz to 300 MHz, noise level decreases as $D^{-1.0}$

Presumably the factor 1.65 is somewhat valid between 1.7 MHz and 30 MHz. The information for the 30 MHz to 300 MHz band is based on a few measurements, but it must be appreciated that the mechanism and also the attenuation law are dependent on the type of noise source, for example conductor corona or gap-type discharges at fittings.

The noise levels referred to 20 m from the nearest conductor of a line may, therefore, be corrected to the protected distance, using the following correction formulae:

$$0.15\,\text{MHz to } 0.4\,\text{MHz} \qquad E_p = E_0 - 36\,\lg \frac{D_p}{20}$$

$$0.4\,\text{MHz to } 1.7\,\text{MHz} \qquad E_p = E_0 - 33\,\lg \frac{D_p}{20}$$

where:

E_p is the radio noise level at protected distance, dB (1 μV/m)

E_0 is the radio noise level at 20 m, dB (1 μV/m)

D_p is the protected distance (m)

Note. – Numerous measurements in the medium frequency band have demonstrated that, on average, the noise level decreases as $D^{-1.65}$ close to the line (see Sub-clause 4.2 of C.I.S.P.R. Publication 18-1). For greater distances, however, some measurements have shown that it decreases as D^{-1}. For any distance greater than about 100 m, a more accurate value for the noise level E_p may be given by:

$$0.4\,\text{MHz to } 1.7\,\text{MHz} \quad E_p = E_0 - 23 - 20\,\lg \frac{D_p}{100} \qquad D_p > 100\,\text{m}$$

There is a degree of uncertainty as to the lateral distance beyond which this formula applies. In most cases, however, at distances beyond 100 m the noise level will be so low that broadcast reception will not be affected.

2.3.5.2 *Distance of measurement*

Whenever possible, measurements should be made at a distance of 20 m from the nearest conductor. When this is not possible, the above formulae may be used to convert measured values taken at other distances to the standard C.I.S.P.R. distance of 20 m. Measurements should also be taken at distances other than 20 m for verification purposes. In all cases, measured profiles of lateral attenuation are greatly preferable to the use of correction formulae (see also Sub-clause 1.2.3).

2.4 *Methods of determining compliance with limits*

The approximate radio noise level due to conductor corona may be predicted for a power line by use of an empirical formula, such as is presented in Sub-clause 2.2 of C.I.S.P.R. Publication 18-3 or with the help of the catalogue (Appendix B of C.I.S.P.R. Publication 18-1). Reliable

prediction of noise levels is important as no corrections of line design or construction can economically be made after the line has been built. Once the line is in service, there are several alternative measurement procedures by which this predicted level may be verified. The choice of method will depend on the length of time available for the measurements and on the degree of accuracy required.

2.4.1 *Long-term recording*

This is the most precise method for evaluating the noise level produced by a power line but it takes a long time to obtain the results. A noise-recording station is set up close to the power line under investigation and continuous measurements are made for at least one year. The suitability of the recording site must be checked by means of measurements at various points along the line. The results are plotted on a probability graph of the type shown in Figure 3 of Publication 18-1. At the percentage of time that has been selected for specifying the noise, the level is read from the graph.

2.4.2 *Sampling method*

This is a practical and accurate method that follows the spirit of C.I.S.P.R. Recommendation 46/1. At least 15 or preferably 20 or more individual sets of measurements of noise level are carried out at various locations along the line and under various weather conditions. The selection of different weather conditions should be more or less in proportion to the percentage of time each weather condition exists in the area of the power line. These measurements are then analyzed to give the noise level that will not be exceeded for 50%, 80%, or 95% of the time, with an 80% confidence, according to the chosen criterion (see Sub-clause 2.3.1).

The sampling method is fully described in Sub-clause 1.4 for the case where the chosen criterion is the 80% level.

2.4.3 *Survey methods*

If time or any other reason does not allow either of the above methods to be used, the alternative of making measurements in fair weather or heavy rain may be considered. This can be adequate when conductor corona is the main noise source and when the radio noise distribution curves for the particular type of line for the all-year-round weather conditions are available. These curves could, for instance, have been obtained from previous accurate measurements on the actual or on the same type of line under similar climatic conditions. Preferably three distribution curves should be available; (1) under fair weather conditions, (2) under heavy rain and (3) under all-year-round weather conditions. Statistical distributions are discussed in Sub-clause 4.2.3 of C.I.S.P.R. Publication 18-1. It should be noted that the methods outlined in the two following paragraphs do not apply to lines below 72.5 kV where conductor corona is not the major source of radio noise.

Fair-weather measurements have to be made at various locations along the line and at different times. From the results, the 50% fair-weather level is deduced and used as a reference in the set of curves mentioned above. From the curves the all-weather 80% value can then be assessed. The success of this method is dependent on the reliability of the distribution curves. In general the 80% all-weather value is from 5 dB to 15 dB higher than the 50% fair-weather value, depending on the climate.

Since the radio noise level due to conductor corona is relatively stable and reproducible during heavy rain, these measurements are not required to be taken at separate times. Foul-weather measurements should also be made at various locations along the line. The 50% steady, heavy, rain level is deduced from the results of the measurements and used as a

reference in the set of distribution curves to assess the 80% all-weather level. Here also the success of the method is dependent on the reliability of the distribution curves, although it is considered that the assessment of the 80% all-weather value from the heavy-rain measurements is more reliable than the assessment from the fair-weather measurements. In general, the 80% all-weather level is about 5 dB to 12 dB lower than the 50% steady, heavy, rain level.

2.4.4 *Alternative criterion for acceptable noise level*

One of the alternative criteria for acceptable noise levels, as discussed in Sub-clause 2.2, may be used. If, for example, the average fair-weather noise level is chosen, then a series of measurements should be carried out during typical fair weather conditions. At least three measurements should be carried out at three different locations along the line. If time permits, this should be repeated on another day. The average of all the measurement values will be considered to represent the average fair-weather noise level of the line.

2.5 *Examples for derivation of limits*

2.5.1 *Radio reception*

Examples of the calculation of limits are given below based on the assumptions discussed in the preceding sub-clauses. Limits could also be calculated for different assumptions in respect of signal level, signal-to-noise ratio and distance from a power line. Conversely, for a given level of noise, the minimum acceptable distance, for satisfactory reception of a given signal strength, could be calculated.

It should be borne in mind that the lateral attenuation laws quoted are average values. They depend on factors relating to both line design and local conditions. They may change with distance and should not be used for distances materially beyond those assumed in this sub-clause.

Furthermore, it should be remembered that radio-noise is generally measured at a frequency of 0.5 MHz. If a signal at a specified broadcast frequency is to be protected, the measured values should be corrected for the given frequency according to Sub-clause 4.2.1 and Figure B 12 of C.I.S.P.R. Publication 18-1. For example, at 1 MHz, the noise level would be about 5 dB to 6 dB lower.

2.5.1.1 *Principle*

There are four parameters involved in the specification of radio noise limits (see Figure 11, page 80):

- the minimum signal level to be protected;
- the minimum acceptable signal-to-noise ratio;
- the reference noise level, 20 m from the nearest conductor, during prescribed weather conditions;
- the "protected distance", that is, the minimum distance from the line at which the signal can be satisfactorily received.

If any three of these parameters are specified, the fourth can be determined. Two examples will demonstrate this.

2.5.1.2 *Example 1*

If the value of the noise level at 20 m from the nearest conductor, the protected signal level and the required signal-to-noise ratio are all known, the protected distance from the power line for satisfactory radio reception in the low and medium frequency bands may be calculated from the formula given in Appendix F.

In the m.f. band, this formula is accurate for distances up to about 100 m.

As an example, the distance from a given power line at which a signal of 72 dB (1 μV/m) at 1 MHz may be received with a signal-to-noise ratio of 35 dB is required. The line noise measured by the standard C.I.S.P.R. method is found to be 50 dB (1 μV/m). The following calculation is made:

Protected signal level at 1 MHz	$S_p = 72$ dB (1 μV/m)
Required signal-to-noise ratio	$R_p = 35$ dB
Acceptable noise level at protected distance from line	$N_p = S_p - R_p$ $N_p = 37$ dB (1 μV/m)
Measured noise level 20 m from nearest conductor at 0.5 MHz	50 dB (1 μV/m)
Noise level at 1 MHz (The 6 dB correction comes from Figure B12 of C.I.S.P.R. Publication 18-1.)	$E_0 = 50-6 = 44$ dB (1 μV/m)
Protected distance	$D_p = 10^{\left(\frac{44+35-72}{33}+1.3\right)}$

Therefore $D_p = 32$ m from nearest conductor.

2.5.1.3 *Example 2*

In this second example a broadcast signal at 1 MHz, 65 dB (1 μV/m), is to be protected with a signal-to-noise ratio of 30 dB at distances greater than 100 m from the power line. The acceptable reference noise level at 20 m is calculated as follows:

Protected signal level at 1 MHz	65 dB (1 μV/m)
Acceptable noise level at protected distance from line	65 − 30 = 35 dB (1 μV/m)
Attenuation from 20 m to 100 m	$33 \lg \frac{100}{20} = 23$ dB
Acceptable reference noise level at 20 m from nearest conductor, at 1 MHz	35 + 23 = 58 dB (1 μV/m)
Therefore, acceptable reference noise level at C.I.S.P.R. reference frequency (0.5 MHz) (The 6 dB correction comes from Figure B12 of C.I.S.P.R. Publication 18-1.)	58 + 6 = 64 dB (1 μV/m)

2.5.2 *Television reception, 47 MHz to 230 MHz*

This is under consideration. Insufficient information is presently available to permit presentation of meaningful examples.

2.6 *Additional remarks*

Most field tests to date have been carried out in the low and medium frequency bands. Therefore, any data presented on the v.h.f. band should be considered as provisional and major conclusions should not be based on it. This whole subject is still under consideration.

If limits are based on noise levels measured and statistically evaluated in accordance with Sub-clause 1.4, they also represent statistical values not exceeded for 80% of the time. For conductor corona noise it should be noted that these values are significantly higher than average fair weather levels. This factor should be taken into account when these values are compared with standards for typical fair-weather conditions laid down in various countries.

As in the case of other sources of possible interference for which C.I.S.P.R. limits exist, examples of limits presented here are based on the requirements for the protection of reception for the large majority of listeners or viewers under conditions prevailing at the majority of sites during most of the time. Such values cannot cater for the few exceptional cases where a number of unfavourable factors coincide.

Practice has shown that acceptable noise levels in this clause can be met with well-maintained power lines of adequate design and construction. Indeed, considerably lower levels are found on many operational lines where requirements other than radio noise lead to designs with larger conductor sizes (for example high current-carrying capacity). It is considered that the methods of deriving limits indicated in this clause represent good engineering practice and could serve as the basis for establishing such limits.

2.7 *Technical considerations for derivation of limits for line equipment and substations*

The principle for establishing limits of radio noise voltage for line insulators and fittings and substation plant and fittings in the l.f. and m.f. bands shall be that their contribution to the aggregate noise level of a transmission line is negligible. This is applicable to a.c. lines whose conductors are subjected to surface gradients of about 12–14 kV/cm or higher. This principle pre-supposes coordination between noise produced by insulators and fittings on the one hand and noise produced by line conductor corona on the other hand. For other a.c. lines, with a lower surface gradient, the noise voltage for line equipment shall be at least as low as the noise voltage for equipment used on lines with a surface gradient of about 12 kV/cm. This principle is applicable to d.c. lines but no figures of gradient are quoted as the relationship between conductor corona noise and noise produced by insulators and fittings is not well established (see Sub-clause 8.2 of C.I.S.P.R. Publication 18-1) the corona noise being higher in dry weather and lower in wet weather. Sub-clause 1.3 describes the C.I.S.P.R. method of radio noise measurement in the laboratory. Sub-clause 6.2 of C.I.S.P.R. Publication 18-1 gives the correlation between the radio noise voltage measured in microvolts, in the C.I.S.P.R. test circuit, due to any noise source (Sub-clause 1.3) and the radio noise field on site, in microvolts per metre, measured in accordance with the method described in Sub-clause 1.3.

For frequencies above a few megahertz, the correlations between the radio noise voltage and the corresponding radio noise field given in Sub-clause 6.2 of C.I.S.P.R. Publication 18-1 do not apply. This means that no principle for establishing limits for frequencies above the m.f. band can be laid down at present.

The radio noise field near a substation, generated by noise sources within the substation, may be the aggregation of the direct radiated field and the guided field due to currents injected into an overhead line serving the substation. At present, insufficient data are available on the radiated component and therefore only the injected currents will be discussed. Coordination between the injected noise currents and the currents produced by line conductor corona applies in this case also.

2.7.1 *Current injected by line components and fittings*

To evaluate the relative influence of insulators and conductors, it is sufficient to compare the current generated by a complete insulator set with the aggregate current I_L generated by a span of one phase conductor of the line. If the current generated by the insulator set is less than I_L, its contribution to the aggregate noise field of the line will be small; if it is equal to I_L, the increase

in level due to the insulators will be approximately 3 dB; if it is greater than I_L, the noise field of the line will be determined mainly by the effect of the insulators.

If the limit of the current of the insulator set is specified as $I_L/3$, that is 10 dB below the current I_L, the increase in the aggregate noise field will be about 0.5 dB. This increase is too small to be measured in practice.

In addition to insulator sets, other components and fittings such as spacers, vibration dampers and aircraft warning devices have to be considered. If for any one of these types of component or fitting there are N items per span the radio noise level per item should not be greater than $1/\sqrt{N}$ times the level for an insulator set.

The aggregate radio noise current per span from all these components and fittings should, according to experience, be determined by quadratic summation of the individually measured currents.

2.7.2 *Current injected by substation equipment*

The equipment is considered as a generator of radio noise current, as indicated in Sub-clause 6.2 of C.I.S.P.R. Publication 18-1. The problem consists in studying the propagation of the injected current along the line, that is, the attenuation and distortion of the guided electromagnetic field associated with this current. To do this, modal analysis is employed.

A substation normally has more than one associated line each with one or more circuits. For determination of the current injected into one of the circuits, it is necessary to know not only the impedance of all circuits but also the impedance of the substation equipment, consisting of busbars, measuring devices, transformers, capacitors, cables, etc., as seen from the apparatus acting as a current source. The current in the circuit under consideration can then be calculated.

For the worst case, the impedance of the substation equipment could be assumed to be infinite. Then for N pieces of apparatus, each producing the same value of noise current I_0, and for n outgoing circuits, the current injected into a circuit is

$$I = I_0 \frac{\sqrt{N}}{n}$$

Clearly the case of a substation with only one circuit is the most unfavourable.

If the current calculated in this way is equal to the value of the current produced by line conductor corona, the increase in the radio noise field at the substation terminal tower will be approximately 3 dB but after 1 or 2 km the additional noise current, and consequently the increase in the field, will be insignificant.

2.7.3 *Practical derivation of limits in the l.f. and m.f. bands*

a) Line components and fittings

The rigorous procedure is as follows: starting from the graph of the excitation function and the matrix of the line capacitances (see Sub-clause 5.2 of C.I.S.P.R. Publication 18-1), the current I injected per unit length of a phase conductor is calculated. To pass from this elemental current I to the aggregate current, generated by a span of length L, the law of quadratic summation is applied:

$$I_L = I\sqrt{L}$$

When comparing the current generated by a complete insulator set with the aggregate current I_L, it is advisable to include a margin of 10 dB in order to ensure a negligible increase in

the aggregate level of the noise field. The value of insulator noise current used in the comparison should be the maximum obtained under the normal range of weather conditions for the area over which the proposed line will run.

For practical purposes, a simple relationship can be derived from the formula (6) given in Sub-clause 6.2.1.2 of C.I.S.P.R. Publication 18-1.The current I from a single insulator set should not exceed the value given by:

$$I = E - 27 - K_1$$

where:

I is in dB (1 μA)

E is the permissible radio noise field strength during reference weather conditions, in dB (1 μV/m), at a distance of 20 m from the nearest conductor of the line

K_1 is the difference in decibels between the conductor corona noise level in the reference weather conditions and that in weather conditions in which the maximum insulator noise level is generated

The formula includes the above-mentioned margin of 10 dB.

b) Substation plant and fittings

The total current I injected into a line by a substation should not exceed the value given by:

$$I = E - 12 - K_2$$

where:

I is in dB (1 μA)

E is the permissible radio noise field strength during reference weather conditions, in dB (1 μV/m), at a distance of 20 m from the nearest conductor of the line, derived from the relevant example in Sub-clause 2.5

K_2 is the difference in decibels between the conductor corona noise level in the reference weather conditions and that in weather conditions in which the maximum substation noise level is generated

This formula is derived from formula (4) given in Sub-clause 6.2.1.2 of C.I.S.P.R. Publication 18-1 for a conductor height h of 15 m and a depth of penetration into the ground P_g of 7 m. No provision has been made for a margin.

At the junction between a line and substation busbars there will usually be an impedance mismatch. This may create standing waves of radio noise on the first few kilometres of the line resulting in a variation of up to ± 6 dB close to the substation. This is not taken into account in the formulae given above.

Notes 1. — These limits are derived from the permissible radio noise field strength for a line.

2. — The main difficulty in the practical application of this principle is to simulate the service conditions for the test objects in the laboratory. As mentioned in Sub-clause 6.3 of C.I.S.P.R. Publication 18-1, there is at present no agreed procedure for simulating in the laboratory the more common service conditions but the matter is under consideration. Meanwhile, it is proposed that measurements should be made on equipment in a situation closely related to service conditions.

3. — Limits for individual items of plant, for example switch disconnectors, circuit breakers, etc., cannot be specified in this publication as these items are the responsibility of other bodies. However, the effect of these individual items, when in their service environment, must be in accordance with the limits discussed above.

BIBLIOGRAPHY AND REFERENCES

(Continuation of the bibliography of C.I.S.P.R. Publication 18-1)

[56] D. Riviere, R. Parraud, C. Gary, M. Moreau, D. Khoutova, J. Vokalek: *The Influence of Ambient Conditions on the Interference Level of Insulator Strings,* CIGRÉ Report 36.04, 1972.

[57] P. D. Bernardelli, R. Cortina, M. Sforzini: *Laboratory Investigation on the Radio Interference Performance of Insulators in Different Ambient Conditions,* IEEE Transactions on Power Apparatus and Systems, vol. PAS-92, January/February 1973, pp. 14-24.

[58] *Radio Noise Design Guide for High Voltage Transmission Lines,* IEEE Committee Report, IEEE Transactions on Power Apparatus and Systems, vol. PAS-90, March/April 1971, pp. 833-842.

[59] Y. Sawada, T. Sugimoto, M. Ushirozawa: *Radio Noise and Corona Loss of 500 kV Power Transmission Line and Substation,* CRIEPI Report No. 7 (Japanese), Central Research Institute of Electric Power Industry (CRIEPI), Japan, June 1970.

[60] IEEE Tutorial Course (1976): *The Location, Correction and Prevention of ri and tvi Sources from Overhead Power Lines.*

[61] CCIR XIV Plenary Assembly, Kyoto 1978, vol. VIII *Recommendation 560,* vol. XI Recommendations 417-2, 418-3.

[62] International Telecommunication Union: *Radio Regulations,* 1982.

[63] International Telecommunication Union: *Final Acts of the Regional Administrative L.F./M.F. Broadcasting Conference,* Geneva, 1975.

[64] North American Regional Broadcasting Agreement, 1950. Annex 2, Appendix B.

[65] *FCC Rules and Regulations,* United States Government, Sections 73.683, 73.684.

[66] Department of Communications, Government of Canada, Broadcast Procedure No. 5: *Protection and Coverage Rules for V.H.F. Television Allocations in Canada.*

[67] C.I.S.P.R. Recommendation 46/1: *Significance of C.I.S.P.R. Limits* C.I.S.P.R. Publication 16.

APPENDIX A

RADIO INTERFERENCE MEASURING APPARATUS DIFFERING FROM THE C.I.S.P.R. BASIC STANDARD INSTRUMENTS

In addition to the instruments specified in C.I.S.P.R. Publication 16, which are the basic reference instruments for determining compliance with C.I.S.P.R. limits in the frequency range 0.15 MHz to 300 MHz, there are instruments of other types used for radio noise measurements on power lines and high-voltage equipment.

In the United States and Canada, ANSI (American National Standards Institute) standard instruments which have quasi-peak detectors with a charge time constant of 1 ms and a discharge time constant of 600 ms have been generally used below 30 MHz. Above 30 MHz the C.I.S.P.R. and ANSI time constants are practically the same. At a given frequency below 30 MHz the ANSI meter usually reads 1 dB or 2 dB higher than the C.I.S.P.R. meter when measuring corona noise. New ANSI standards under consideration incorporate the C.I.S.P.R. specifications for the quasi-peak detectors.

Instruments with detectors other than quasi-peak which include r.m.s., average and peak detectors are specified in C.I.S.P.R. Publication 16. These instruments should be used for standard measurements only when conversion to quasi-peak values is possible. Although C.I.S.P.R. Publication 16 gives the conversions to quasi-peak values for periodically repeated pulses, these conversions do not apply to corona pulses which occur in bursts (see Sub-clause 1.1.1).

APPENDIX B

LIST OF ADDITIONAL INFORMATION TO BE INCLUDED IN THE REPORT ON THE RESULTS OF MEASUREMENTS ON OPERATIONAL LINES

When the results of measurements are reported, the following additional information should be included:

a) Conductor surface voltage gradient – r.m.s. value for system voltage at time of measurements. State, in the case of bundles, if gradient is average or maximum.

b) Atmospheric conditions at measurement sites: temperature, pressure (altitude), humidity, wind speed, etc.

c) Pollution of conductors, insulators and fittings. State if "light","moderate" or "severe" pollution and, if possible, the type of pollution, for example, cement or saline and the resistivity of the equivalent saline mist.

d) Type of insulator – if radio noise measurements, according to Sub-clause 1.3, have been made on a complete insulator set of this type, the information should be included.

e) Conductor configuration including:

i) presence or not of earth conductor;

ii) number of conductors per phase and relative disposition;

iii) nature of conductor;

iv) height of conductors above ground at measurement site.

f) Age of line.

g) Line support – metal tower or wood or concrete pole.

h) Distance from nearest substation, transposition and angle structure and the presence or not of line traps for carrier communication equipment.

i) Distance from other lines or sources of interference which may affect the measurements.

j) Whether the results are from a single measurement or from a statistical assessment. Data from a statistical assessment may conveniently be presented in statistical form using cumulative probability paper. Results may be summarized by quoting the noise levels exceeded for 5%, 20%, 50%, 80% and 95% of the time.

k) The period over which the measurements have been made. For a full assessment of the radio noise performance of a high voltage line, only measurements made over a sufficiently long period may be considered as significant.

l) Resistivity of the soil, if known.

m) The line loading (where this may be important).

APPENDIX C

MINIMUM BROADCAST SIGNAL LEVELS TO BE PROTECTED – ITU RECOMMENDATIONS

For the l.f. and m.f. bands the ITU has established, for three climatic zones (A, B and C), the minimum field strength necessary to overcome natural noise (atmospheric noise, cosmic noise, etc.) [63]. These levels, which have been determined by adding 40 dB to the value of natural noise distribution exceeded for 10% of the time, are given in Table CI:

TABLE CI

Minimum field strength

	Zone		
	A	B	C
Frequency (MHz)	Field strength in dB (1 μV/m)		
0.15 0.28	73 70.5	83 80.5	76 73.5
0.5 1.0 1.6	65 60 57	75 70 67	68 63 60

For broadcast planning purposes, the ITU has also recommended nominal usable field strengths. These recommendations, including the footnotes, are reproduced here for the 0.5 MHz to 1.7 MHz and 0.15 MHz to 0.28 MHz bands. The exact values of upper and lower limits of the various frequency bands, for different regions of the world, can be found in [62].

The nominal usable field strength values are shown in Table CII below in dB (1 μV/m).

TABLE CII

Nominal usable field strength

	Zone A	Zone B	Zone C
A. Medium frequency (0.5 MHz to 1.7 MHz)			
Daytime ground-wave service	63	73	66
Night ground-wave service [1]			
– rural areas [2]	71	81	74
– urban areas	77	87	80
Low-power channels	88	88	88
B. Low frequency (0.15 MHz to 0.28 MHz) [3]	77	87	80

[1] Where the transmitter power is sufficiently high for the ground-wave service area to be limited by fading due to the sky-wave of the same transmitter, a nominal usable field strength greater than the value given in the table may be chosen. It should not, however, be greater than the ground-wave field strength at the beginning of the fading zone. The fading zone may be defined by taking the protection ratio between the ground-wave and the sky-wave to be equal to the internal protection ratio applicable to a synchronized network, that is 8 dB.

[2] Some delegations consider a nominal usable field strength of 65 dB (1 μV/m) to be suitable for rural areas in their countries.

[3] Certain delegations consider a value of nominal usable field strength of the order of 73 dB (1 μV/m) to be appropriate in non-tropical rural areas.

APPENDIX D

MINIMUM BROADCAST SIGNALS TO BE PROTECTED – NORTH AMERICAN STANDARDS

In North America, the signal levels at the edge of the service area of a broadcast station, according to NARBA and other standards [64], [65], [66] are:

TABLE D I

Signal levels at the edge of the service area in North America

Service	Frequency (MHz)	Signal levels (dB (1 μV/m))
AM radio	0.5 to 1.7	54
	Some "Class A" stations	40
V.H.F. television (Channel 2 to 6)	54 to 88	47
V.H.F. television (Channel 7 to 13)	174 to 216	56

APPENDIX E

REQUIRED SIGNAL-TO-NOISE RATIOS FOR SATISFACTORY RECEPTION

A.M. radio broadcasting

Although no exact recommendations concerning acceptable signal-to-noise ratios have been devised for interference from power lines, a number of tests have been conducted throughout the world. These are summarized in reference [66]. In these tests, the noise was measured with either a C.I.S.P.R. meter or a meter satisfying ANSI Specification C63.2-1969. For measurement of the signal, some investigators used the quasi-peak detector and others used the average detector.

Table E I shows all the data, corrected to represent signals measured with an average detector and noise measured with the quasi-peak detector of a C.I.S.P.R. meter. Table E II defines the codes for quality of reception used in Table E I. Average rather than quasi-peak measurement of the signal level seems logical since signal levels, as defined by international bodies such as CCIR and NARBA, are average or r.m.s. values of the modulated signal.

For the development of limits, any of the ratios in Table E I could be used. It is not possible at present to state which is the most accurate. As a guide, the last column of Table E I shows the mean of all the values for each quality of reception.

Television broadcasting

Some signal-to-noise ratio tests have been conducted for power line noise in the v.h.f. television bands. The results indicate that a 40 dB ratio, with the signal measured by an average detector and the noise measured by a C.I.S.P.R. meter, with a quasi-peak detector, may be satisfactory. However, this subject is still under consideration.

TABLE E I

Summary of signal-to-noise ratios for corona from a.c. lines
(Signal measured with average detector, noise measured with quasi-peak detector)

Canadian Voluntary Standard		IEEE Radio Noise Design Guide		Lippert Pakala *et al.*		Taylor *et al.*		Gehrig *et al.*		Nigol		CIGRÉ		Hirsch		De Michelis and Rosa		Mean
Code	Ratio (dB)	Code	Ratio (dB)	Code	Ratio (dB)	Code	Ratio (dB)	Code	Ratio (dB)	Code	Ratio (dB)	Code	Ratio (dB)	Code	Ratio (dB)	Code	Ratio (dB)	
A1	39	–	–	–	–	0	41	–	–	–	–	–	–	–	–	–	–	40
A2	31	A5	31	A	31	1	35	–	31	5	–	5	30	1	30	0	36	32
B	26	B4	26	B	26	2	29	–	26	4	25	4	24	2	20	1	30	26
C	21	C3	21	C	21	3	23	–	21	3	21	3	18	3	14	2	24	20
D	15	D2	15	D	15	4	18	–	16	2	15	2	12	4	8	3	17	15
E	9	E1	4	E	7	5	12	–	10	1	–	1	6	5	–	4	10	8
–	–	F0	–	F	–	6	6	–	–	0	–	0	0	–	–	5	2	3

TABLE E II

The codes shown in Table E I, defining the quality of reception or degree of annoyance, as used by the various investigators are summarized below.

Canadian Voluntary Standard

A1 Entirely satisfactory for classical music
A2 Satisfactory for general listening
B Background noise reasonably unobtrusive
C Background noise evident
D Background noise very evident
E Difficult to understand.

IEEE Radio Noise Design Guide

A5 Entirely satisfactory
B4 Very good, background unobtrusive
C3 Fairly satisfactory, background plainly evident
D2 Background very evident, but speech easily understood
E1 Speech understandable only with severe concentration.

Lippert, Pakala, Bartlett, Fahrnkopf

0 Excellent
1 Entirely satisfactory
2 Very good
3 Fairly satisfactory
4 Speech easily understood
5 Speech understandable
6 Speech unintelligible.

Gehrig, Peterson, Clark, Rednour

Background not detectable
Background detectable
Background evident
Background objectionable
Difficult to understand
Unintelligible.

Nigol (Burrill's Code)

5 Entirely satisfactory
4 Very good, background unobtrusive
3 Good, background evident
2 Program easily understood, background very evident
1 Program badly distorted, background very evident
0 Program unintelligible.

CIGRÉ

5 Interference not audible
4 Interference just perceptible
3 Interference audible, but speech perfectly received
2 Unacceptable for music, but speech intelligible
1 Speech understandable only with severe concentration
0 Spoken word unintelligible; noise swamps speech totally.

TABLE E II *(continued)*

Hirsch

1 Very good reception, no disturbance detectable
2 Good reception, disturbance without severe nuisance
3 Satisfactory reception, disturbance evident
4 Sufficient reception, distorted with very evident noise
5 Insufficient reception, program unintelligible.

De Michelis and Rosa

0 No interference. No disturbance perceived
1 Barely perceptible. Disturbance audible during conversation in a low voice, but not during conversation in a normal voice
2 Perceptible. Disturbance audible in any case but not particularly irritating
3 Somewhat objectionable. Disturbance audible even during musical broadcast
4 Definitely objectionable. Irritating but perfectly intelligible
5 Intolerable. Extremely irritating disturbance with reduced intelligibility.

APPENDIX F

DERIVATION OF FORMULA FOR PROTECTED DISTANCE

The formula used in the examples in Sub-clause 2.5.1 is derived as follows:

The acceptable noisc level at the protected distance is:

$$N_P = S_P - R_P$$

where:
N_P is the acceptable noise level at D_p, in dB (1 μV/m)
S_P is the protected signal level, in dB (1 μV/m)
R_P is the required signal-to-noise ratio, in decibels
D_P is the protected distance, in metres

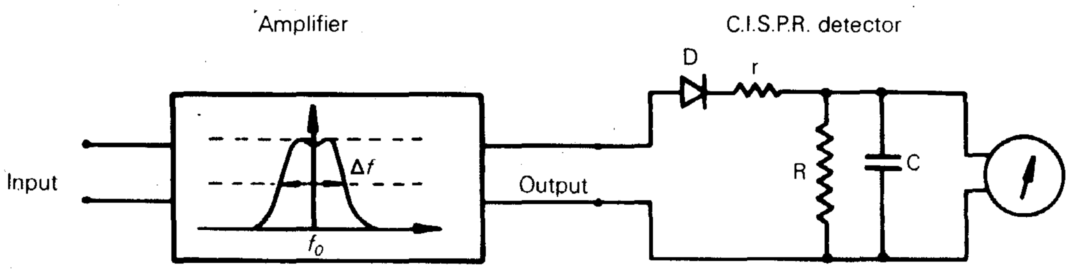
But using the attenuation formula given in Sub-clause 2.3.5.1:

$$N_P = E_0 - K \lg \frac{D_P}{20}$$

where:
E_0 is the noise level at 20 m from the nearest conductor, in dB (1 μV/m)
K = 36 for l.f. band
33 for m.f. band

$$S_P - R_P = E_0 - K \lg \frac{D_P}{20}$$

$$\text{Therefore: } D_P = 10^{\left(\frac{E_0 + R_P - S_P}{K} + 1.3\right)}$$



Δf = band width
f_0 = centre frequency
D = diode
r = charging resistor
R = discharging resistor
C = capacitor

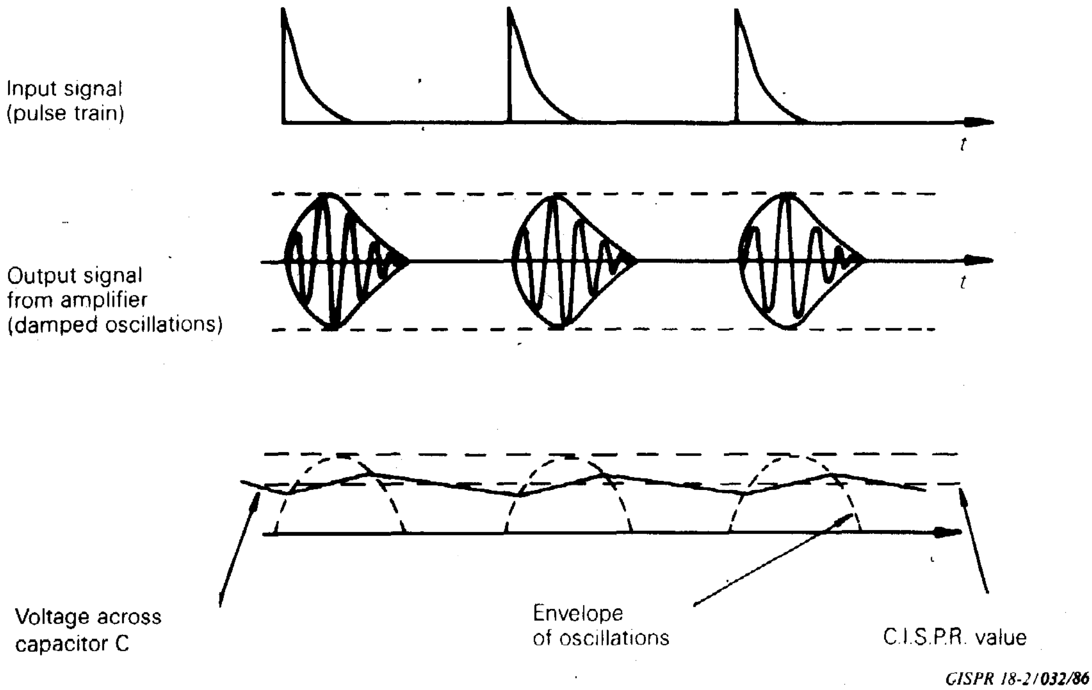


FIG. 1. – Transformation of pulses through a C.I.S.P.R. measuring set.

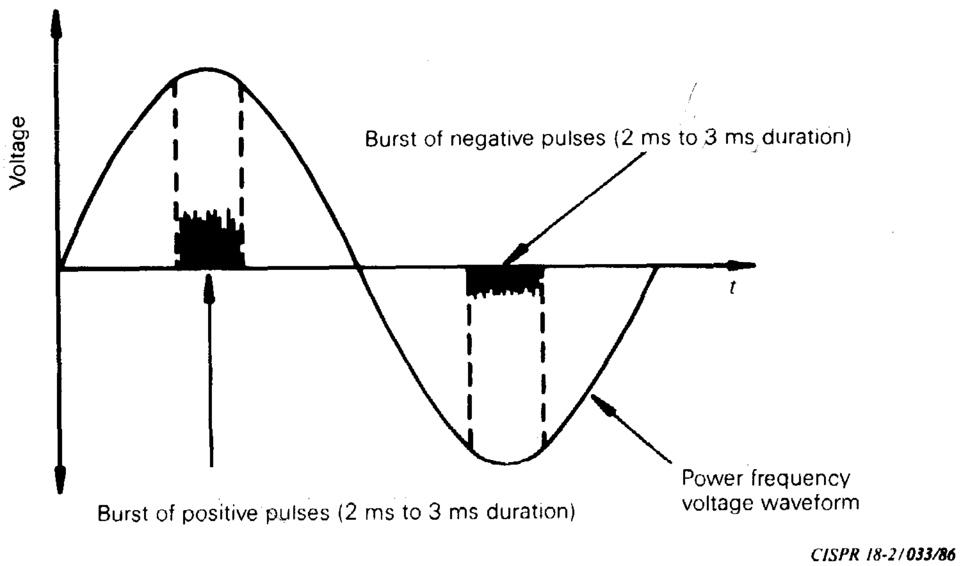
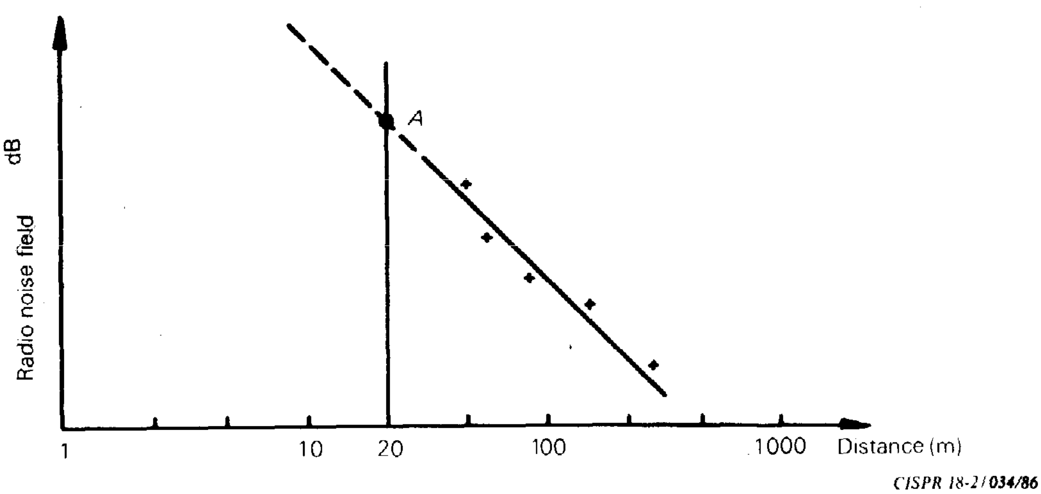


FIG. 2. – Bursts of corona pulses generated by alternating voltage.



Reference level A Measured levels ×

FIG. 3. – Example of extrapolation to determine the radio noise field reference level of a power line.

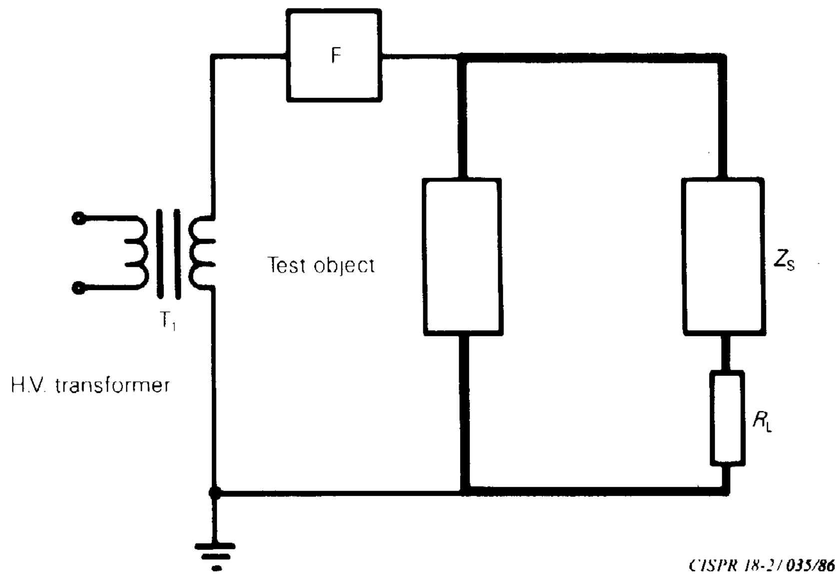
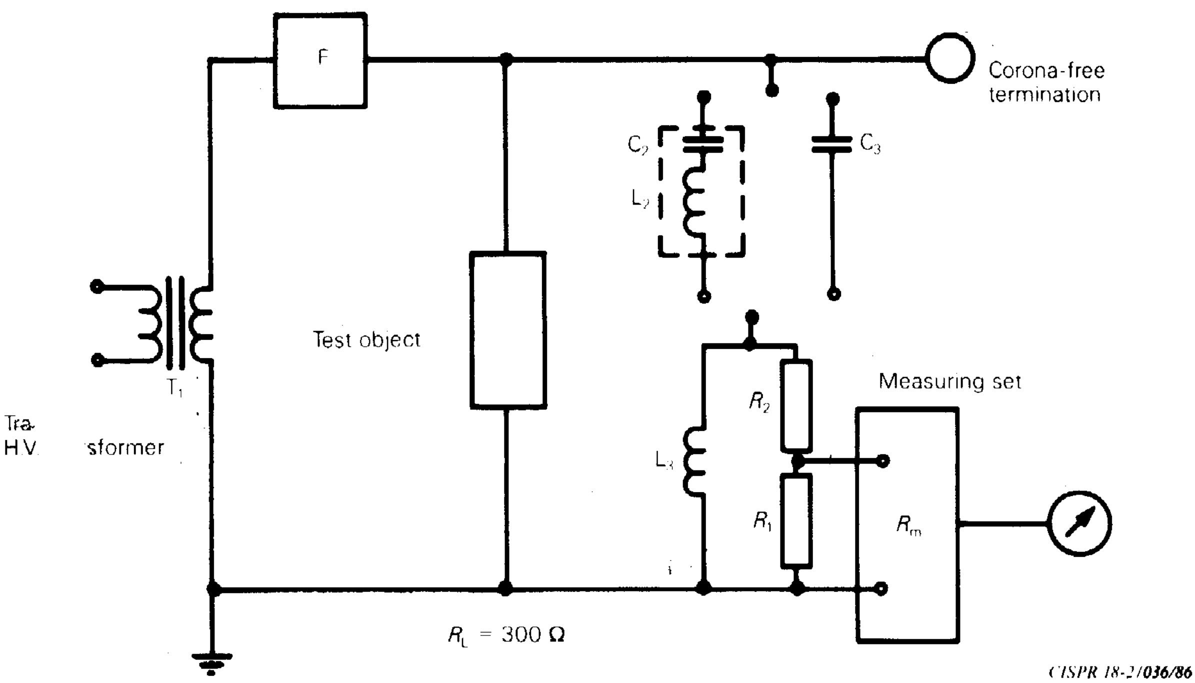


FIG. 4. – Basic test circuit.



Note. – Filter F may be aperiodic or consist of L_1 in parallel with C_1.

FIG. 5. – Standard test circuit.

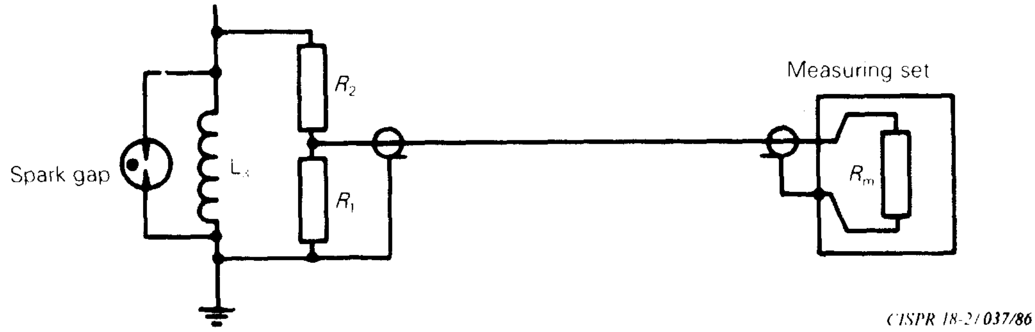


FIG. 6. — Measuring set connections balanced cable.

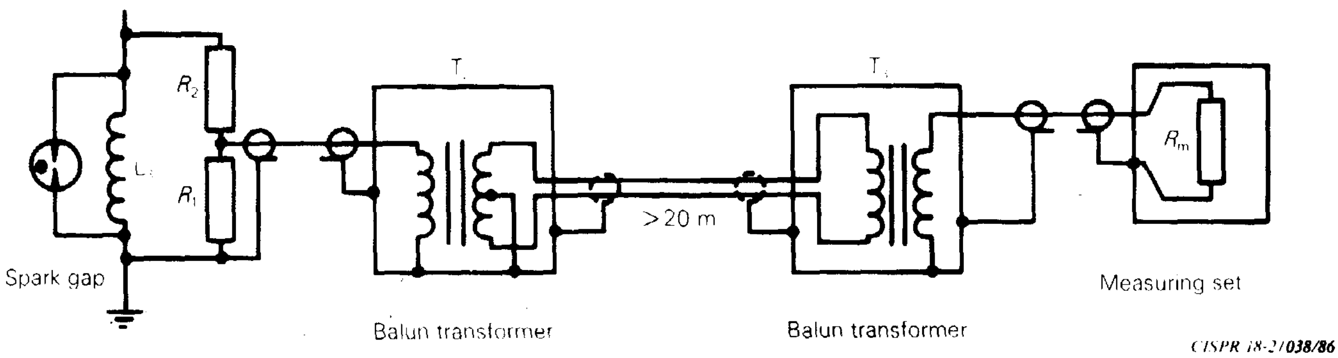


FIG. 7. — Measuring set connections co-axial cable.

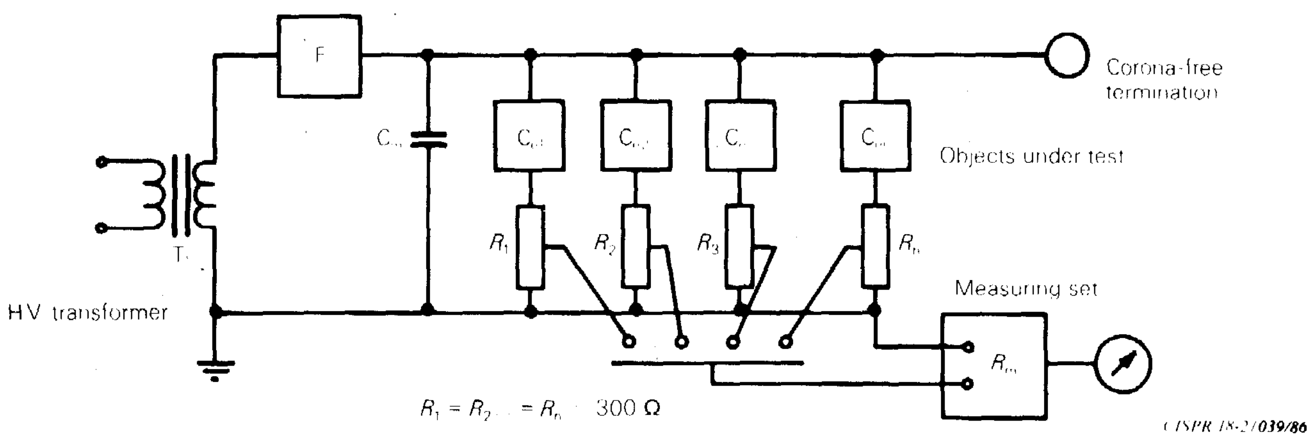


FIG. 8. — Special test circuit.

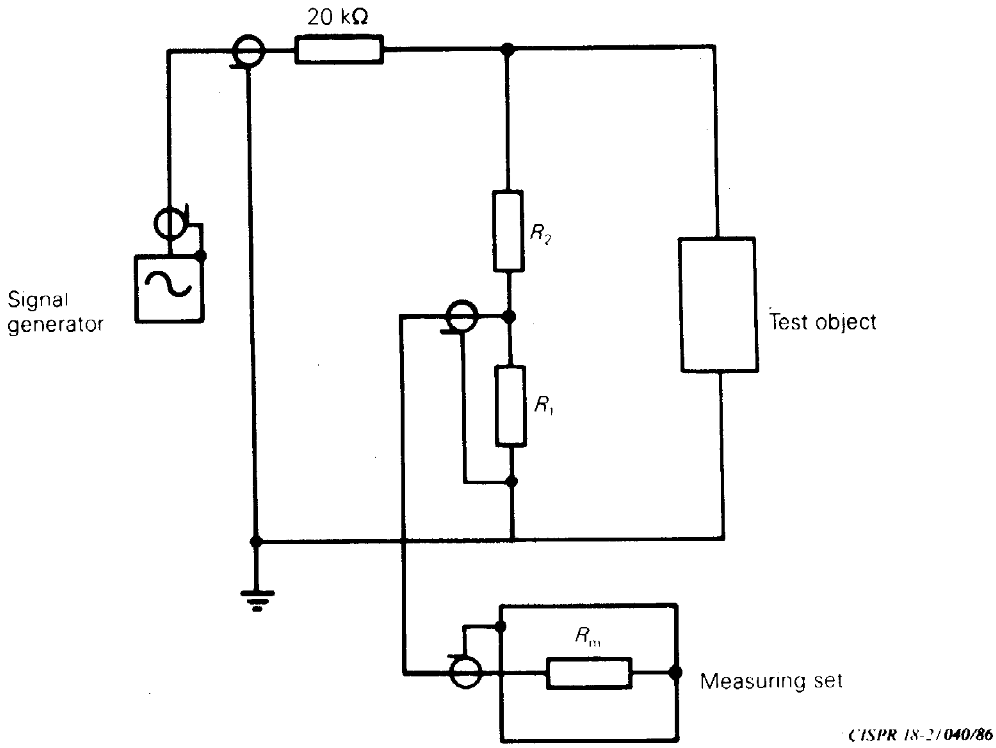
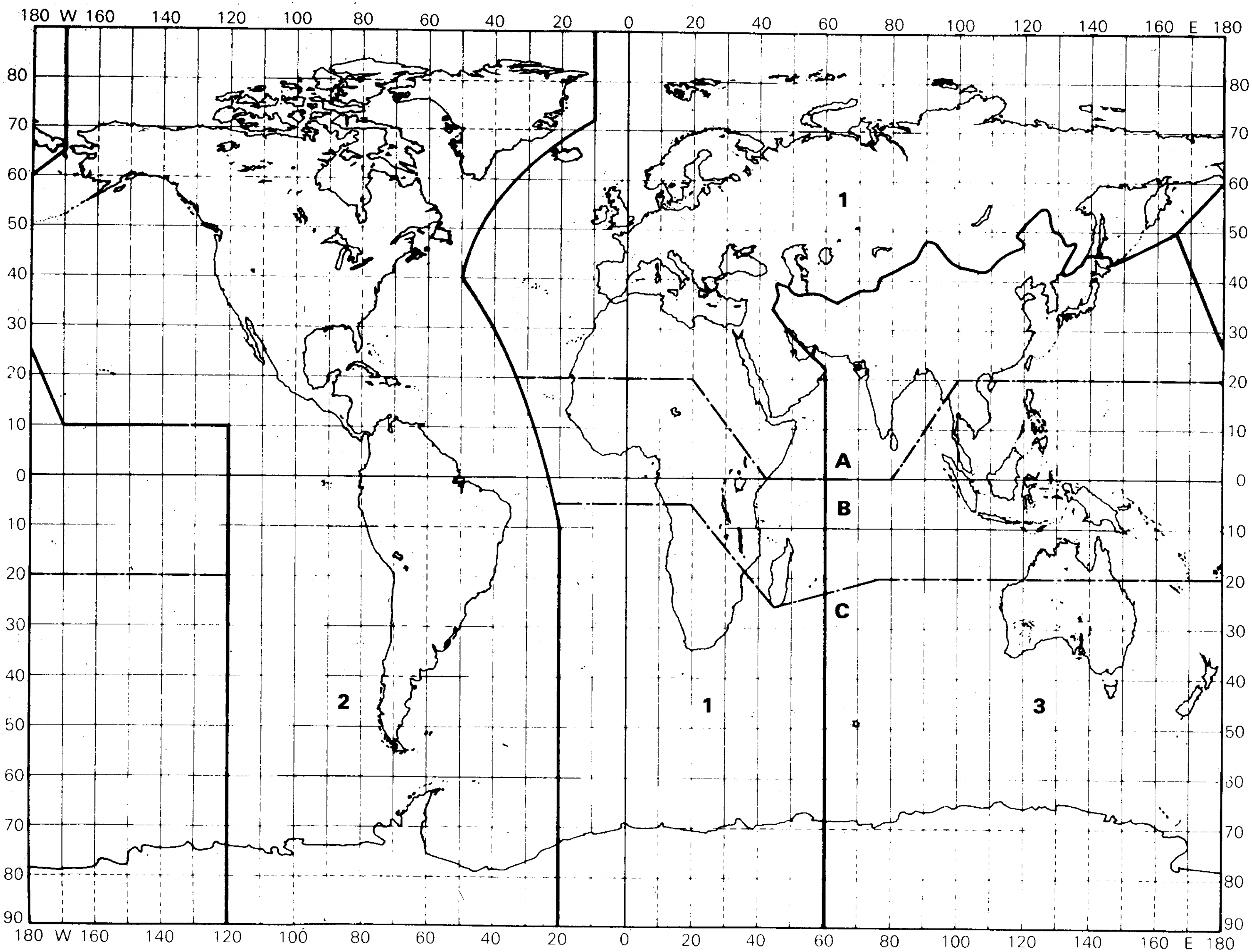


FIG. 9 — Arrangement for calibration of standard test circuit.



CISPR 18-2/041/86

FIG. 10. — Map showing boundaries of Zones A, B and C in Regions 1 and 3.

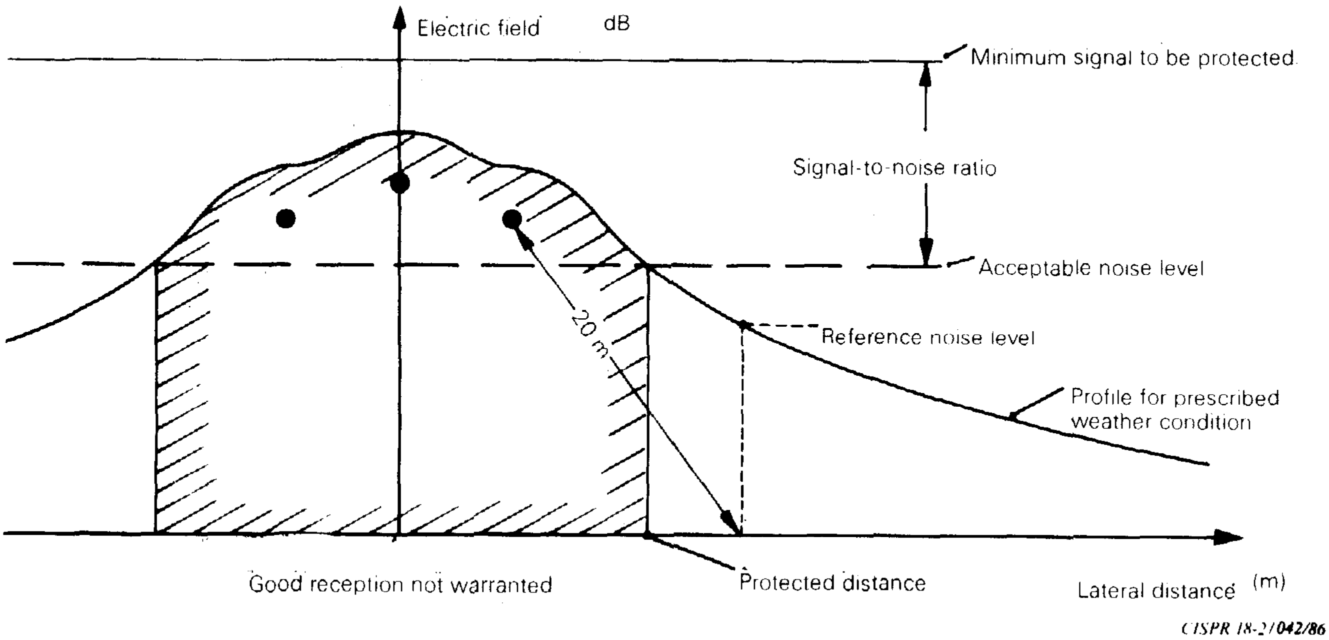


FIG. 11. — Illustration of the four basic parameters.

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(Continued from second cover)

In the adopted standard, reference appears to certain International Standards for which an Indian Standard also exist. The corresponding Indian Standard which is to be substituted in their places are listed below along with their degree of equivalence of the edition indicated.

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
CISPR Pub 16 (1977)	IS 10052 : 1992 Specification for electromagnetic interference measuring apparatus and measurement methods	Technically equivallent
CISPR Pub 18-1 (1982)	IS 12233 (Part 1) : 1987 Electromagnetic interference characteristics of overhead power lines and high-voltage equipment : Part 1 Description of phenomena	Technically equivallent
IEC Pub 60-2 (1973)	IS 2071 (Part 2) : 1974 Methods of high-voltage testing : Part 2 Test procedures	Technically equivallent

The concerned technical committee has examined the provisions of the IEC 437 and C.I.S.P.R Pub 18-3 referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard.

This Indian Standard is being issued in three parts as follows:

Part 1 Description of phenomena

Part 2 Methods of measurement and procedure for determining limits

Part 3 Code of practice for minimizing the generation of radio noise

NATIONAL EXPLANATORY NOTES

1 In **2.3.3** the minimum signal levels to be protected are applicable to countries in Region I. For India, which is in Region III, following limits as specified by ITU are applicable:

Frequency Band	*Minimum Signal Strength*	
Television band I, 47 MHz to 68 MHz	46 dB (microvolt/m)	
FM radio band II, 87 MHz to 108 MHz	48 dB (microvolt/m)	(for mono)
	54 dB (microvolt/m)	(for stereo)
Television band III, 174 MHz to 230 MHz	49 dB (microvolt/m)	
Band IV	58 dB (microvolt/m)	
Band V	64 dB (microvolt/m)	

2 In **2.3.4.1.** the wanted-to-interfering signal ratio of 30 dB has been specified for LF/MF bands. For HF broadcasting bands, the ITU recommends the Signal-to Noise ratio of 34 dB for planning purposes.

3 In Appendix C, Table C II specifies nominal useable field strength for medium and low frequency. For the planning of HF bands allocated to the broadcasting service, ITU recommends that the minimum useable field-strength should be determined by adding 34 dB to the greater of:

— the field strength due to atmospheric radio noise

— 3·5 dB (microvolt/m) which is the intrinsic receiver noise level

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard.

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